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BULLETIN

OF THE

AMERICAN PHYSICAL SOCIETY

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PROGRAMME OF THE SEATTLE MEETING

AT

THE UNIVERSITY OF WASHINGTON,

SEATTLE, WASHINGTON

June 27–29, 1949

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BULLETIN

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AMERICAN PHYSICAL SOCIETY

SEATTLE MEETING, JUNE 27–29, 1949

THE **294th meeting of the American Physical Society** will be held at the University of Washington, Seattle, on Monday, Tuesday, and Wednesday, June 27–29, 1949. A meeting of the American Association of Physics Teachers will also be held in Seattle on the 29th and 30th of June. On the afternoon of June 29 there will be a joint session of the two societies. The continuity and programme for the two groups will permit those physicists who wish to attend or participate in the activities of the American Physics Teachers to do so more intensively on the following day. An interesting program has been arranged.

The University of Washington is located in the northern part of Seattle. It is easily reached from downtown Seattle either by taxicab or by transit buses Nos. 4, 7, or 8, alighting from the bus at the 40th Street entrance to the campus. The morning sessions will be held in the physics lecture rooms in Physics Hall, and the afternoon sessions will be held in the auditorium of the new Health Sciences Building.

The Registration Desk will be in the Physics Department Library, Room 215, Physics Hall. Information concerning programs, housing, restaurants, and entertainment may be obtained at this desk.

Comments on invited papers. A varied program of invited papers has been arranged. The invited papers will come on the afternoons of June 27, 28, and 29, the third afternoon being a joint session with the American Association of Physics Teachers.

There will be no official banquet of the American Physical Society at this meeting. Instead it is hoped that members of the Society will take advantage of the many local facilities for outdoor entertainment. In addition, the local campus theater has been reserved for the evening of June 28. Tickets may be obtained at time of registration.

Hotels. A number of hotel rooms have been guaranteed by the Hotel Edmond Meany which will be the official headquarters of the Society and which is located in the University District within walking distance of the meeting. Hotel rooms have also been promised by the following downtown hotels which are approximately four miles away: Benjamin Franklin Hotel, Mayflower Hotel, Olympic Hotel, and the New Washington Hotel. Since there are a number of conventions meeting concurrently in Seattle, it is essential that reservations be made promptly at these hotels. It is important that the American Physical Society be mentioned in the letter to the hotel. In addition, a number of motels in the vicinity are suggested as possible accommodations. These are: Davis Motel, 2510 Aurora; Ace Motel, 8512 Aurora; Sun Hill Lodge, 8517 Aurora; North Seattle Motel, 11522 Aurora; Seal's Motel, 120th & Aurora; Lou-Al Cabins, 8601 20th N.E.; Royal Motor Court, 10745 Aurora; City Center Motel, 224 Aurora. These motels are recommended by the American Automobile Association and are within easy driving distance of the campus.

Special notice to those interested in outdoor activities. The Pacific Northwest abounds in opportunities to those interested in outdoor life. Aid in arranging the following activities will be given: mountain climbing excursions; summer skiing; fishing, both fresh and salt water (salt water fishing requires no license); and yachting trips. It is recommended that members interested bring as much outdoor equipment as possible.

Post-deadline papers. The Council, availing itself of an amendment to the By-Laws adopted on 30 January 1948, announces that "The Council or its designates will consider the admission, to a special supplementary programme, of a limited number of papers of which the abstracts are received not later than Friday 24 June." These abstracts must reach the office of Dr. J. Kaplan (University of California, Los Angeles 24, California) by the specified time. Do not regard this as a guarantee of acceptance!

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The idea is to make possible the presentation of a small number of very recent achievements of very special importance. The abstracts of the post-deadline papers which are accepted will not be published: the titles will be announced, and the papers will be scheduled for presentation at a convenient time or times during the meeting.

General Rules Relating to Papers

The time allowed for the oral presentation of a contributed paper is ten minutes at most. The time allowed for the oral presentation of each invited paper is stated in the Bulletin.

When two or more papers are contributed by the same member, all but one are placed on the "supplementary programme." (A paper by two or more members is credited, for this purpose, to the person first named in its by-line.) For each paper on this programme a session will be announced by the Secretary at which it may be presented. The presiding officer at this session may call for it when the other papers are completed, may require that it be given in fewer than ten minutes, or may read it by title.

Titles and abstracts of the papers contributed to the Seattle meeting are printed in the following pages. Proofs of the abstracts have not been submitted to the authors, and the proofreading is always cursory because of the need for haste: but the authors have opportunity to correct their proofs before the abstracts appear in the Physical Review. Overlong abstracts sometimes appear in a form unexpected by the authors, because there is not time to consult them before the abstracts are amputated to fit the requirements stated on the summons card.

Acknowledgment. The Secretary wishes to acknowledge the excellent help of Professor E. A. Uehling in arranging the program of invited papers and in the general planning of the meeting.

J. Kaplan
Local Secretary for the Pacific Coast
University of California
Los Angeles 24, California

PROGRAMME

MONDAY MORNING AT 9:30

Physics Hall, Room 320

(C. L. UTTERBACK presiding)

Contributed Papers

A1. Forbidden Oxygen Lines in Afterglows.* S. KASH AND J. KAPLAN, *University of California, Los Angeles.*—A remarkable luminescence which appears to be associated with the green oxygen auroral line has been reported by Vegard and Kvifte[1] and by Jenkins, Bowtell, and Strong.[2] This appears to be the same effect which was first observed by one of us[3] in an unusually strong green line afterglow in nitrogen-oxygen mixtures. The spectrum published in 1942 shows a continuous shading on the short wave-length side of the green line. This shading was not present in the vicinity of the forbidden oxygen line 2972. Current studies of intensity variations in this strong green line afterglow have shown clearly that the green line and the associated line 2972 follow a different intensity-time relationship than does the forbidden nitrogen line 3467 in the same afterglow. The two oxygen lines decay much more slowly than do all other features of the afterglow spectrum. The continuous spectrum which accompanies the green line shows the same intensity-time behavior as do the two forbidden lines which originate on the $^1S_0$ level. Further studies of these effects in other oxygen forbidden line sources are in progress.

* This work is being carried on under an ONR contract.
[1] L. Vegard and G. Kvifte, Nature, No. 2, 967 (1948).
[2] Jenkins, Bowtell, and Strong, Nature, **163**, 401 (1949).
[3] J. Kaplan, Nature, **149**, 273 (1942).

A2. Propagation Rate of Streamers in High Pressure Sparks. B. A. JACOBSOHN, *University of Washington.*—The formative time for sparks at high pressures and large gap lengths is related to the rate of propagation of the streamer head back to the cathode. The propagation mechanism, which has been described by Loeb,[1] depends on photo-ionization near the streamer tip by ultraviolet photons of short mean free path. The crude model for streamer advance to be presented here includes the effect of those photons emitted in all directions. Thus the advance of the streamer head is governed by a diffusion equation which takes into account the "random walk" performed by the photons and the efficiency of each absorbed photon in eventually producing g new photons. If g is only slightly greater than one (small overvoltage), the region in which a critical positive ion density exists is not extended for some time after the passage of the first electron avalanche; after this delay time, the streamer propagates with high velocity. This is to be contrasted with models which lead to uniform streamer tip velocities.

[1] L. B. Loeb, Rev. Mod. Phys. **20**, 151 (1948).

A3. Transients in the Phenomena of Nuclear Induction. E. A. UEHLING, *University of Washington.*—The influence of the thermal relaxation time T_1 on the character of nuclear induction signals has been exhibited frequently as the time of approach to steady-state conditions when a change has been made in $\Delta\omega$, the difference of Larmor and exciting frequencies. In order to obtain a more quantitative examination of this phenomenon, transient solutions of the nuclear induction equations, valid for excitation amplitudes which are not arbitrarily small, but for modulation amplitudes which are much less than the line widths have been obtained. These solutions exhibit two types of approach to equilibrium: an approach without oscillation at a time constant nearly equal to T_1, and an approach with oscillation at a frequency determined by the final state and at a time constant nearly equal to the transverse relaxation time T_2. Under appropriate conditions, the solution dependent essentially on T_1 may be exhibited separately providing the radiofrequency field amplitude is greater than $1/\gamma(1/T_2-1/T_1)$, where γ is the gyromagnetic ratio.

A4. Nuclear Induction Proton Signals Below Noise Level from Gases at One Atmosphere.* F. BLOCH AND DAVID H. GARBER,** *Stanford University.*—A photographic method has been developed for observing nuclear induction signals with magnitude below the noise level of the associated detection and amplification stages. The signal together with the accompanying camouflaging noise is displayed in the usual manner on a cathode-ray oscillograph with linear sweep. A time exposure of several thousand traces is taken; the random nature of the noise contributes a horizontal, more-or-less uniform ribbon most dense in the middle, with the small recurrent signal observable at the top and bottom edges of the ribbon. The contrast obtained is enhanced by use of a high contrast film and by further contrast copying. Optimum or experimentally limiting conditions will be discussed for choice of contrast, exposure time, vertical sharpness of CRO beam, and band width of amplifier. Proton signals will be shown, obtained from samples of propane and of hydrogen gas, at one atmosphere pressure. A new design is employed for splitting the r-f transmitter coils which surround the receiver coil and sample; this eliminates difficulties of tuning and re-assembly previously accompanying changes of samples.

* Assisted by the ONR and the Research Corporation.
** Now at the University of Washington.

A5. Nuclear Resonances in Rotating Magnetic Fields.* E. H. ROGERS AND H. H. STAUB, *Stanford University.*—The sign dependence of the nuclear induction phenomenon has been observed by obtaining proton signals in purely rotating radiofrequency magnetic fields. It will be recalled[1] that the nuclear induction effect demands a radiofrequency field rotating about the direct current field in a direction which corresponds to the direction of Larmor precession of the nucleus under consideration. Ordinarily the rotating field is obtained from one rotating component of an oscillating field. As a consequence the direction of rotation of the precessing nuclei cannot be determined. In this new device the required field was produced by two pairs of coils oriented at right angles to one another and fed by two r-f currents differing in phase by 90°. Proton signals appeared and disappeared according to the direction of rotation of the r-f field around the d.c. field. By setting up elliptically polarized fields, various combinations of signal magni-

tudes were observed according to expectation. The device was constructed for and is currently being used to make a direct comparison of the signs of the magnetic moments of the neutron and the proton. The method for observing neutron resonances is similar to that described previously.[2]

* Assisted by the Joint Program of the ONR and AEC.
[1] F. Bloch, Phys. Rev. **70**, 460 (1946).
[2] Bloch, Nicodemus, and Staub, Phys. Rev. **74**, 1025 (1948).

A6. Collision Theories of Pressure Broadening of Spectral Lines.* J. H. VAN VLECK, *Harvard University*, AND HENRY MARGENAU, *Yale University*.—It is shown that in the calculation of absorption in the Lorentz collision theory, it is essential to include the work done impulsively by the electric field during the sudden change of position at collision. This work was implicitly included in the theory of Van Vleck and Weisskopf, but they did not give the breakdown into work done between and at collision. It is verified that the shape of spectral lines for a classical harmonic oscillator, and also a Debye slow rotator, are the same in absorption and spontaneous emission, provided the energy density obeys the Rayleigh-Jeans law. The usual proofs of equilibrium simply establish equality of the integrated absorption and emission, without examining the detailed balancing at individual frequencies, not necessarily near resonance.

* Supported in part by the ONR.

A7. Pressure Dependence of the Inversion Frequency of NH_3.* HENRY MARGENAU, *Yale University*.—Several experiments (Bleany and Penrose, Weingarten) on the shape of the inversion lines of NH_3 have indicated an effective decrease in the inversion frequency with increasing pressure of the gas. This is to be expected on theoretical grounds, as was suggested in a forthcoming publication. The interaction of two NH_3 molecules causes the doublet levels to change their spacing. It is shown that *two* transitions of different frequencies occur when the molecules approach each other, one smaller and one larger than the normal value and given by $\nu_0[(1+\lambda^2)^{\frac{1}{2}} \mp \lambda]$. Here λ is the dipole interaction energy divided by the normal doublet spacing. When transition probabilities are calculated it is seen that the smaller frequency gains in strength upon approach of the molecules, at the expense of the other. The pressures at which the reduction in the resonance frequency is observed correspond to the distances of separation between molecules at which the effect here calculated sets in.—The preceding comments have reference to non-rotating molecules. Our calculation includes the rotation and shows that the deformation described is superposed upon the interaction (Margenau and Warren) previously discussed.

* Supported in part by the ONR.

A8. Waves Guided by a Single Surface. F. J. ZUCKER, *Electronics Research Laboratories*, USAF. (*Introduced by R. E. Hiatt.*)—Among the many possible modes known in electromagnetic theory, there is one type which enables energy to be propagated along a smooth or periodic interface between two media. This mode is characterized by the very rapid attenuation of the amplitude away from the guiding surface. Energy is transported along flow lines undulating from one medium into the other and back again, the relative amount of time spent in each depending on their constitutive parameters. A general discussion of the theory in its mathematical aspects is followed by a brief enumeration of several optical phenomena in which the mode arises (total internal reflection, Wood's anomalies in diffraction gratings,* reflection from metal mirrors), and of its connection with other fields of physics (molecular beams, acoustics). The type of mode in question has applications in microwave physics as well. It enables energy to be transported along single sheets or rods, both smooth or corrugated. Structures of this type lend themselves as radiators. Experimental verification of the theory will be displayed in several illustrative examples.

* U. Fano, Ann. d. Physik **5**, 32/5 (1938).

A9. The Measurement of Electrical Anisotropy of High Polymers at Microwave Frequencies. T. M. SHAW AND J. J. WINDLE, *Western Regional Research Laboratory*.*—Techniques are described for measuring the electrical anisotropy of natural and synthetic high polymers at microwave frequencies. A cylindrical cavity resonator operating in the TM_{010} mode at 3000 mc/sec. is used to determine the dielectric constant of the polymer for various orientations with respect to the electric field of the cavity. Appropriate procedures permit the method to be applied to solids of practically any form. Specific examples are given of measurements on fibers, films, and cylindrical rods.

* Bureau of Agricultural and Industrial Chemistry, Agricultural Research Administration, U. S. Department of Agriculture.

A10. Solenoidal Beta-Ray Spectrometer with Uniform Magnetic Field. F. H. SCHMIDT, *University of Washington*.—The theory of the ring focus has recently been discussed.[1,2] The results of a different approach to the focusing problem are here reported. An offset ring baffle[2] is used. For a point source the resolution is found to be a maximum at 55° 20′ emission angle. The inverse momentum resolution is then $\Delta p/p = 6.5(\Delta\Phi)^2$, where $\Delta\Phi$ is the fractional solid angle transmitted. The resolution is quite flat and decreases by only 20 percent at emission angles of 40° and 68°. For a source of finite surface area perpendicular to the axis of the instrument, the optimum emission angle is $43° \pm 1°$ under conditions of constant luminosity (source area times solid angle). Again, the resolution at constant luminosity decreases by only 20 percent at angles 32° and 60°. By adopting the resolution criterion of DuMond,[2] and equating the aberration due to finite disk source to that due to the finite solid angle, the following optimum conditions at 43° are obtained: $\Delta p/p = 12(\Delta\Phi)^2$, source diameter $= 1.16R\Delta p/p$, where R = maximum distance between trajectories and axis of the instrument. Thus, a $\Delta p/p$ of $\frac{1}{2}$ percent should be obtainable with a 2 percent $\Delta\Phi$. Such an instrument is under construction and will be described.

[1] E. Persico, Rev. Sci. Inst. **20**, 191 (1949).
[2] J. W. M. DuMond, Rev. Sci. Inst. **20**, 160 (1949).

Invited Paper

A11. Recent Developments in Electron Microscopy. L. MARTON, *National Bureau of Standards*. (35 min.)

MONDAY AFTERNOON AT 2:00

Auditorium of the Health Sciences Building

(J. E. HENDERSON presiding)

Invited Papers

B1. Recent Advances in Quantum Electrodynamics. R. P. FEYNMAN, *Cornell University.* (30 min.)

B2. High Energy Gamma-Rays from the Cyclotron Target. BURTON J. MOYER, *University of California, Berkeley.* (30 min.)

B3. Proton-Proton Scattering. WOLFGANG K. H. PANOFSKY, *University of California, Berkeley.* (30 min.)

B4. Recent Theoretical Work at the Radiation Laboratory. M. L. GOLDBERGER, *University of California.* (30 min.)

TUESDAY MORNING AT 9:30

Physics Hall, Room 320

(E. A. UEHLING presiding)

C1. Neutron Polarization. J. FLEEMAN AND H. H. STAUB, *Stanford University.*—The time-of-flight method has been used to obtain a monoenergetic beam of neutrons in order to determine the cross section for the polarization of neutrons by magnetized iron. We obtain the following results: (1) The measured values of p as a function of the velocity of the neutrons are in good agreement with those obtained by Hughes;[1] they are roughly 6 percent smaller than the calculated values of Steinberger and Wick,[2] using the third wave function with zero slope at the atomic radius. (2) The velocity spectrum of the neutron beam was measured and we find that it deviates somewhat from a Maxwell-Boltzmann distribution at room temperature, as expected. From these measurements, the modification of the spectral composition of the neutron beam upon passage through iron can be calculated. From measurements of the single-transmission effect at thicknesses ranging from 0.6 cm to 5.0 cm it is found that the average value of p, for the spectrum used in the present experiment, is 2.33 ± 0.10 barns in agreement with previous results.[3] The dependence of magnetic saturation upon H is also in satisfactory agreement with previous magnetic measurements.[3]

[1] Hughes, Wallace, and Holtzmann, Phys. Rev. **73**, 1277 (1948).
[2] J. Steinberger and G. C. Wick, Phys. Rev. **74**, 1207 (1948).
[3] Bloch, Hamermesh, and Staub, Phys. Rev. **64**, 47 (1943); Bloch, Condit, and Staub, Phys. Rev. **70**, 972 (1946).

C2. Proton Induced Activities in Tantalum. J. W. BURKIG AND J. REGINALD RICHARDSON, *University of California, Los Angeles.*—When tantalum is bombarded with 12-Mev protons, the following activities are observed: one or possibly two periods in the range 15 to 20 minutes, an activity of eight hours half-life, and a long period activity. Excitation functions have been obtained indicating a very steep rise of the eight-hour period with increasing proton energy, and a threshold at six Mev. This corresponds to the reaction $Ta^{181}(p, pn)Ta^{180}$, except that the threshold is somewhat lower than that reported for the (γ, n) reaction and may indicate the presence of some (p, d) reaction. In the case of the long period, however, the excitation function is less steep with an ill-defined threshold below 4 Mev. This corresponds to the reaction $Ta^{181}(p, n)W^{181}$. The half-life of W^{181} is 140 days.[1] The energy spread of the proton beam has been checked by the usual foil-wheel technique. The width at half maximum of the current *vs.* energy curve is 0.5 Mev. The excitation function of the short period activity is complex. This may indicate the presence of two activities of approximately this period. This work was supported in part by the joint program of the ONR and the AEC.

[1] G. Wilkinson, Nature **160**, 864 (1947).

C3. The Q Value for $B^{10}(p\alpha)Be^7$. C. Y. CHAO, C. C. LAURITSEN, AND A. V. TOLLESTRUP, *California Institute of Technology.*—From the Q values for $B^{10}(p\alpha)Be^7$ and $Li^7(pn)Be^7$ and the energy of the first excited state of Li^7, the Q values for $B^{10}(n\alpha)Li^7$ and $B^{10}(n\alpha)Li^{7*}$ can be calculated. The energy of this latter group of α-particles is of particular interest since, together with their range determined by Bøggild[1] and also by others, it gives a fixed point in the range-energy relation for slow α-particles. From threshold measurement, the Q value of $Li^7(pn)Be^7$ has been determined to be 1.646 ± 0.002 Mev[2] while several recent investigations have yielded 0.478 ± 0.001 Mev for the energy of the first excited state of Li^7. The α-particles from $B^{10}(p\alpha)Be^7$ have been studied by bombarding a thin evaporated layer of B^{10} enriched B_2O_3 with protons from an electrostatic generator. The α-particles emerging from the target at a mean angle of 137.8° with the incident beam were analyzed by a double focusing magnetic spectrograph and detected with a scintillation counter. The Q value for $B^{10}(p\alpha)Be^7$ is found to be 1.148 ± 0.005 Mev which is somewhat higher than the value 1.05 ± 0.07 found by Burcham and Freeman.[3] Our value leads to 2.794 ± 0.006 Mev for the Q value of $B^{10}(n\alpha)Li^7$ and 2.316 ± 0.006 Mev for that of $B^{10}(n\alpha)Li^{7*}$. This work was assisted by the joint program of the ONR and the AEC.

[1] J. K. Bøggild, Kgl. Danske Vid. Sels. Math.-fys. Medd **23**, No. 4, 1 (1945).
[2] Herb, Snowdon, and Sala, Phys. Rev. **75**, 246 (1949).
[3] W. E. Burcham and J. M. Freeman, Nature **163**, 167 (1949).

C4. Magnetic Analyzer for Electrostatic Generators. D. B. DUNCAN, *California Institute of Technology.*—A magnetic analyzer has been constructed for use with the new electrostatic generator. The beam from the generator is deflected through 90° with a radius of curvature of 16 in. An "H type" cross section is employed so that the return path for almost all of the flux is in iron, thereby minimizing the interference of the stray field with nearby apparatus. By shaping the pole pieces so that the field varies as $r^{-\frac{1}{2}}$ point for point focusing properties are obtained.[1,2] A parallel beam is focused 17 in. from the magnet where slits are located to give energy resolution. The field is measured with a null-reading fluxmeter.[3] The

125 amperes necessary are obtained from selenium rectifiers, the current being regulated by supplying the input to saturable core reactors from the electronically amplified potential drop across a series resistor. This work was assisted by the joint program of the ONR and the AEC.

[1] Svartholm and Siegbahn, Arkiv. f. Mat. Astr. o. Fys. **33A**, No. 21 (1946).
[2] Snyder, Lauritsen, Fowler, and Rubin, Phys. Rev. **74**, 1564 (1948).
[3] C. C. Lauritsen and T. Lauritsen, Rev. Sci. Inst. **19**, 916 (1948).

C5. Application of Proportional Counter to $p-\alpha$ Reactions at 100 Kev. A. W. SCHARDT, E. J. WOODBURY, AND W. A. FOWLER *California Institute of Technology.*—A β-ray mica window counter is used either with original filling or with 20- to 30-cm Hg of a mixture of 90 percent A and 10 percent CO_2. The amplifier[1] has a gain of 10^4 to 10^5 with the shortest time constant 1.6 μsec. The high voltage on the counter is derived from a shunt regulated power supply (600 to 1500 volts) which drifts less than 1.5 volts after initial warm-up. If wide apertures are desired 4 percent to 6 percent of a sphere the pulse heights are not uniform. However 100 percent α-counting is possible in presence of strong β- and γ-ray background. The mica window of the counter is 1.8 mg/cm^2. It is coated with 0.2 mg/cm^2 of aluminum. Thus no scattered protons enter the counter. With 100 μamp. of protons on a clean brass target 1 background count per minute is observed. Investigations are being made on the $N^{15}(p\alpha)C^{12}$ reaction which is of special interest since it is part of the stellar cycle.[2] The target (TiN^{15}) is mounted on an air-cooled brass support. Special care has to be taken to eliminate surface films which can mask completely the true reaction. An improved design of the r-f ion source[3] gives reliably 100 μamps. of protons through a 0.095-in. aperture mounted in front of the target. Preliminary results will be discussed. This work was assisted by the joint program of the ONR and the AEC.

[1] W. H. Jordon and P. R. Bell, Rev. Sci. Inst. **18**, 703 (1947).
[2] H. A. Bethe, Phys. Rev. **55**, 434 (1939).
[3] R. N. Hall, Rev. Sci. Inst. **19**, 905 (1948).

C6. Operation of a Linear Electron Accelerator.* G. E. BECKER AND D. A. CASWELL *Stanford University.*—The traveling wave linear electron accelerator[1] constructed at Stanford has been extended in length to 14 ft. The increase has been made in steps of approximately 2 ft. and at each new length the dependence of the energy spectrum on the frequency power input and injection voltage has been investigated. The energy spectrum is monochromatic in character in that there is a single peak in the curve of electron current *vs.* electron energy. With a length of 14 ft. the peak occurs at 5.7 Mev with a half-width of 1 Mev. The width of the peak is less for shorter lengths and is probably caused in part by the fact that the filling-time for a length of 14 ft. is an appreciable fraction (nearly $\frac{1}{3}$) of the pulse length. The current reaching the target remains of the same order of magnitude as the length is increased. The frequency sensitivity increases with length but the energy spectrum remains good within a frequency range of ± 0.5 mc/sec. Variations of 10 kv from the design injection voltage of 80 kv produce no significant changes in the output.

* Assisted by the ONR.
[1] Ginzton, Hansen, and Kennedy, Rev. Sci. Inst. **19**, 89 (1947).

C7. A High Intensity Cyclotron. E. J. LOFGREN, *University of California Berkeley.*—Preliminary experiments have been carried out on the use of a cyclotron as an injector for the Bevatron. We have obtained 20 ma of 1-mev protons circulating in pulses with a duty cycle of 1:1000. It has been possible to deflect 7 ma and by the use of a wedge-shaped magnetic field to bring $\frac{3}{4}$ ma to a focal spot about $\frac{1}{4}$ in. $\times 1\frac{1}{2}$ in. 8 ft. from the cyclotron. The source is a cold cathode arc inside of a $\frac{1}{2}$-in. diameter tube whose axis is parallel to the field. The ions are withdrawn from a vertical slot in the tube by a pair of slits mounted on one dee. A large change of radius during the first turn is necessary so that the ions shall not strike the source. This condition is met by a magnetic field of 7000 gauss and 70 to 100 kv r-f between dees. A deflector with a longitudinal channel has been successfully used. It makes the deflector insensitive to positional or voltage adjustment since ions deflected too far feel a reduced electric field and move in again. Many suggestions were made by E. O. Lawrence including the channel deflector. This work was sponsored by the AEC.

C8. Total Cross Sections of Nuclei for 40-Mev Neutrons. R. H. HILDEBRAND AND C. E. LEITH, *University of California Berkeley.*—The measurement of the 40-Mev neutron total cross sections of various nuclei will be described. The 40-Mev neutron beam is produced in the 184-in. cyclotron by the stripping[1] of 90-Mev deuterons in a $\frac{1}{2}$-in. thick Be target. The method of detection is that used by Cook, McMillan, Peterson and Sewell[2] in making similar measurements for 90-Mev neutrons. The neutron intensity is measured by counting the 20.5-min. C^{11} positron activity resulting from the $C(n, 2n)$ reaction in carbon disks. The threshold for this reaction is about 20 Mev. The cross sections at 40 Mev will be compared to those at other energies. In the region of O, Mg, and Al the cross sections are only slightly smaller than those measured at 14 Mev [3], whereas, for nuclei heavier than Sn, the cross sections are closer to those measured at 90 Mev.[2] This work was sponsored by the AEC.

[1] R. Serber, Phys. Rev. **72**, 1008 (1947).
[2] L. J. Cook, *et al.*, Phys. Rev. **75**, 7 (1949).
[3] E. Amaldi, *et al.*, Nuovo Cimento **3**, 15, 203 (1946).

C9. Range-Energy Relations for High Energy Protons in Photographic Emulsions. H. BRADNER, A. S. BISHOP, W. H. BARKAS * *University of California, Berkeley.*—Range-energy relations for protons in the region of 30 Mev in nuclear emulsions are of particular interest for the calculation of the mass of artificially produced mesons. The range-energy relations of Lattes, Fowler, and Cüer[1] for protons of energies up to 13 Mev in Ilford B-1 emulsion have been extended to approximately 35 Mev using protons in the 184-in. Berkeley cyclotron. A check point was obtained with the Berkeley linear accelerator. Preliminary measurements at 28.5 Mev yield a range of 3340 μ in 50 μ emulsion evacuated for 5 minutes. The range of 32-Mev protons in the glass of Ilford plates has been found to be 18 percent greater than in C-2 emulsion. Sixteen-Mev tracks were 3 percent shorter in 100 μ C_2 emulsion which had been evacuated for 6 hours, than in emulsion which had been kept at ~80 percent humidity for 6 hours, and then evacuated for 5 minutes. Thirty-three-Mev tracks in 200-μ C_2 emulsion showed an 8 percent difference in the same direction. This work was sponsored by the AEC.

* ONR, San Francisco.
[1] Nature **159**, 301 (1947).

C10. Improved Mass Values for π^-, π^+, and μ^+ Mesons. A. S. BISHOP, H. BRADNER, AND F. M. SMITH, *University of California, Berkeley.*—The two major sources of error in the previously reported values[1] of π^-, π^+, and μ^+, mesons are (a) the uncertainty in the absolute value of the magnetic field of the 184-in. cyclotron and (b) the error in the range-energy relationship for mesons in Ilford C-2 emulsions. Two independent methods of minimizing these errors are being pursued. The most obvious method involves a redetermination of the magnetic field strength by the method of nuclear induction, together with a direct measurement[2] of the range-energy relationship in Ilford C-2 emulsion of protons from 13 to 40 Mev (corresponding to meson energies from 2 to 7 Mev). The second procedure is that of comparing the mass of the meson to that of the proton, when the apparent mass of the latter is also determined by $H\rho$ and range. In this way, approximate cancelation of the above errors can be achieved merely by selecting

for measurement those protons with the same velocity as the mesons being measured. Results from both methods of measurement will be reported. This work was performed under the auspices of the AEC.

[1] A. S. Bishop, Phys. Rev. **75**, 1468 (1949).
[2] Bradner, Bishop, and Barkas (accompanying abstract).

C11. Yield of Negative π-Mesons Produced by High Energy Protons as a Function of Proton Energy.* STANLEY B. JONES AND R. STEPHAN WHITE, *University of California, Berkeley.*—A study is now in progress to find the relative numbers of negative π-mesons created by protons of various energies. The energies were obtained by placing the targets at different radii in the 184-in. Berkeley cyclotron. The study is limited to star-producing mesons with energies of approximately 2–6 Mev emitted within ±45° of the forward direction from a $\frac{1}{32}$-in. carbon target. Eastman type NTB Plates were used to record the mesons. Preliminary data are given in Table I. Column 1 gives the energy of the bombarding protons; column 2, the numbers of mesons actually counted; and column 3, the numbers of mesons relative to the number at 340 Mev, corrected for beam current, plate thickness, and area scanned.

TABLE I.

Beam energy (Mev)	No. of mesons	Corrected relative yield
340	22	100 percent
306	41	43 percent
272	22	27 percent
238	5	5 percent
204	2	1 percent
170	0	0 percent

* This work was performed under the auspices of the AEC.

C12. Temperature Dependence of Structure of Thin Silver Films.* GERALD W. JOHNSON, *State College of Washington.*—Single crystals of silver of thickness 100–1000A grown by thermal distillation of silver upon cleaved rocksalt single crystals were heat-treated at various temperatures in the range 100–500°C. Such films supported by the rocksalt substrate were examined optically under bright field illumination and polarized light at high magnification. No structural changes were noted up to 400°C. In the temperature range of 400–500°C structural changes took place whose nature depended upon the film thickness. For the thinnest films the formation of small nuclei occurred which were similar in appearance to the spherulites observed by Andrade and Martindale.[1] In films of intermediate thickness, rectangular holes appeared with the sides oriented along the 110 direction of the rocksalt. In still thicker films, systems of straight lines were observed which intersected at right angles and were directed along the 110 directions. In the thickest films (1000A) no changes were apparent. All films disintegrated at temperatures above 500°C. The formation of the holes and of the straight lines is attributed to local rupture of the film under tension arising from the difference in expansion of silver and rocksalt.

* Supported by ONR.
[1] E. N. Da. C. Andrade, and J. G. Martindale, Phil. Trans. Roy. Soc. **235 (A)**, 69 (1936).

C13. Surface Self-Diffusion of Silver on Thin Single Crystals.* GERALD W. JOHNSON AND T. WATANABE, *State College of Washington.*—Single crystals of silver of thicknesses in the range of 500–1000A were produced by thermal distillation of silver upon the surface of a freshly cleaved rocksalt single crystal using a technique similar to that of Brück.[1] Subsequently silver enriched with Ag^{110} was deposited in a strip across the previously deposited single crystal which gives then two single crystals in contact with the same orientation. The change in distribution of the radioactive silver was then measured as a function of temperature and time for films of different thicknesses. A scanner was constructed to permit the ready determination of the distribution without destroying the film. Diffusion over distances of 1–2 mm in 24 hours was observed at temperatures as low as 350°C. Diffusion coefficients and activation energies will be given.

* Supported by ONR.
[1] v. L. Brück, Ann. d. Physik **26**, 233 (1936).

TUESDAY AFTERNOON AT 2:00

Auditorium of the Health Sciences Building

(KARL K. DARROW presiding)

Invited Papers

D1. Nuclear Spectroscopy. W. A. FOWLER, *California Institute of Technology.* (30 min.)

D2. Isotopes in Stellar Atmospheres. ANDREW MCKELLAR, *Dominion Astrophysical Laboratory.* (30 min.)

D3. Scattering and Reactions of Protons on Tritons. R. F. TASCHEK, *Los Alamos Scientific Laboratory.* (30 min.)

D4. Direct Crystal Spectroscopy of Gamma-Radiation. DAVID A. LIND, *California Institute of Technology.* (30 min.)

WEDNESDAY MORNING AT 9:30

Physics Hall, Room 320

(J. KAPLAN presiding)

E1. Experimental Method for Determining Relative Stopping Power.* JOHN G. TEASDALE, *University of California, Los Angeles.* (*Introduced by J. R. Richardson.*)—To make use of the small external proton beam (12 Mev) of the 37-in. cyclotron at UCLA for stopping power measurements, a differential ionization chamber and electrometer tube was used. The chamber is arranged so that ions having opposite sign coming from two sections are collected on the grid of a G.E.

5674 electrometer tube. If the beam is very near the end of its range in the differential chamber the grid current is sensitive to energy variations but not to intensity changes. Foils to be compared are alternately inserted into the beam and the thicknesses adjusted so that no change in grid current results from substitution. A sensitivity enabling detection of 0.1 ma/cm² at differences between foils has been used although a greater sensitivity is possible. At this sensitivity the background radiation from the cyclotron is of no consequence. A preliminary check of the relative stopping power per electron for silver, palladium, tantalum, gold, and platinum gives results higher than those reported by E. L. Kelly† (for example ten percent higher for silver). This is not inconsistent with the higher velocity of the particles used.

* This work was in part supported by the joint program of the ONR and AEC.
† E. L. Kelly, Phys. Rev. **75**, 1006 (1949).

E2. Branching Ratio in Be^7 Decay. C. M. TURNER, *University of California, Berkeley.*—A new measurement has been made of the branching ratio in the K capture decay of Be^7 in which about 90 percent of the decays go directly to the ground state of Li^7 and about 10 percent[1] go to the 475 kev excited level with subsequent emission of a γ-ray. This ratio is of interest since it can give information about the selection rules effective in β-decay. The method used is as follows: (1) Geometrically identical samples of Be^7 and C^{11} are made with the proton beam from the Van de Graaff generator using the reactions $Li^7(p, n)Be^7$ and $B^{11}(p, n)C^{11}$. The ratio of activities induced in a manganese bath by the neutrons gives the ratio of the number of activated atoms in the two samples. (2) The targets containing the Be^7 and C^{11} are counted in identical geometry with respect to a Geiger counter with sufficient absorber to convert the positrons from C^{11} decay to annihilation quanta. The annihilation quanta have essentially the same energy as the Be^7 decay quanta and serve to calibrate the counter. Preliminary results indicate that the ratio lies close to 0.1. This work was sponsored by the AEC.

[1] Phys. Rev. **54**, 657 (1938).

E3. Angular Distribution of 10.8 Mev Deuterons Scattered by Deuterons. E. J. STOVALL, JR., J. C. ALLRED, K. W. ERICKSON, AND J. L. FOWLER, *Los Alamos Scientific Laboratory.*—Cross sections for the elastic scattering of deuterons by deuterons have been measured for incident energy of 10.8 Mev at laboratory angles from 17.5° to 57° at 2.5° intervals. The deuteron beam from the Los Alamos cyclotron was focused on a thin target containing deuterium, and the scattered deuterons were detected in a proportional counter. A selsyn controlled foil shutter mounted in front of the counter prevented He^3, and H^3 at angles greater than 40°, from entering the counter. H^1, and H^2 at the smaller angles, were discriminated against by using a ten-channel pulse amplitude analyzer. Typical values of the elastic scattering cross section at 10.8 Mev in barns per unit solid angle are given in the table for several angles in the center of mass system. The standard error of these values is estimated to be ±3 percent. The experimental curve is symmetrical about 90° in the center of mass system.

θ	35°	40°	50°	60°	70°	80°	90°
σ	0.283	0.235	0.158	0.127	0.109	0.099	0.094

E4. On the Theory of Neutron Reflectors for Chain-Reacting Spheres.* G. M. VOLKOFF, *University of British Columbia.*—An expression for the fractional reduction ϵ in the critical radius of a homogeneous neutron multiplying sphere of multiplication constant $k>1$ due to an infinite reflector of multiplication constant $0\leq k'<1$ has been obtained on the basis of elementary neutron diffusion theory and of the following assumptions. The chain reaction is sustained by thermal neutrons. The scattering and slowing-down properties of the reflector are identical with those of the core at all neutron energies. The difference in the resonance escape probability within and outside the core affects only the values of k and k' but does not affect the slowing down process. The problem is formulated as an integro-differential equation which is solved by a method based on the Hopf-Wiener solution of Milne's integral equation. For a general model of the slowing-down process and in particular for the "age-velocity" model a formal approximate solution has been found valid from $k\approx 1$ up to high values of k. The approximation has been checked by finding the exact solution for a special ("synthetic kernel") model of slowing-down which in a certain limit reduces to the "age-velocity" model. The contributions to ϵ of thermal and of fast neutrons have been evaluated separately.

* Based on unclassified reports CRT 391 and 392 of the AEP, National Research Council, Chalk River, Ontario.

E5. Precision Measurement of Half-Lives.* LORNA M. SILVER, *University of British Columbia. (Introduced by G. M. Volkoff.)*—A number of decay periods have been measured using an ionization chamber with a vibrating reed condenser electrometer and feed-back amplifier. The sensitivity of this instrument enables the activity to be followed over 16 periods and hence permits the detection of, and correction for any weak long period background activity. The accuracy of the method for a simple decay, as estimated by the method of least squares, is about 0.4 percent. The main feature of the ionization chamber used was its specimen holder which provided exactly reproducible geometry. The whole apparatus was operated continuously in an underground room at fairly constant temperature and humidity. Periods of activated materials were found as follows:

Cu^{64}	12.88±0.03 hr.
Cu^{66}	4.34±0.03 min.
Ni^{65}	2.50±0.03 hr.
Au^{198}	2.69±0.01 days
In^{116}	53.93±0.13 min.

* This work was carried out at the Chalk River Laboratories of the National Research Council.

E6. Absorption of Alpha-Particles in Gases.* G. G. EICHHOLZ AND N. J. HARRICK, *University of British Columbia.*—A shallow ionization chamber has been used to measure the range of alpha-particles from a thin Polonium source in gases at atmospheric pressure. A chamber of depth 3 mm was used with a preamplifier which formed an integral part of the assembly and preceded a balanced main amplifier. The stopping power of the gases relative to air was obtained from the extrapolated number-distance range using Holloway and Livingston's[1] value for air of 3.897 cm as standard. The following results were obtained:

Gas	Extrapolated range	Stopping power
Argon:	4.185±0.009 cm;	0.931
Deuterium:	16.509±0.029 cm;	0.236
Methane (C.P.):	4.556±0.010 cm;	0.853

* This work was supported by the National Research Council of Canada.
[1] Holloway and Livingston, Phys. Rev. **54**, 18 (1938).

E7. The Half-Life of the Positive π Meson. E. A. MARTINELLI, *University of California, Berkeley.*—Data for the half-life of the positive π-meson has been obtained using essentially the method employed by Richardson* for the determination of the half life of the negative π-meson. This consists of determining the decrease in number beyond geometrical factors of the mesons reaching 180° and those which reach 540° or 900° from the target. Simultaneous exposure of plates at 180° and at one of the other positions is accomplished by utilizing the

helical paths of the mesons in the nearly uniform field of the cyclotron. The mesons are produced by proton bombardment of a carbon target in the 184-in. cyclotron. Several refinements in the method have been introduced which will enable the geometry of the apparatus to be determined to a higher degree of accuracy and also a third point on the decay curve will be determined. Preliminary scanning of the plates shows a half life in agreement with that of Richardson, within the statistics of track counting. This work was sponsored by the AEC.

* J. Reginald Richardson, Phys. Rev. **74**, 1720 (1948).

E8. $N-P$ Scattering Experiments at 280 Mev.* E. KELLY, C. LEITH, C. WIEGAND, *University of California, Berkeley.*—The total $n-p$ cross section and the angular distribution of the scattered protons have been studied with the same method used at 90 Mev.[1] The total cross section is approximately 0.03 barns. The angular distribution will be shown. It varies from about 0.013 barns at 180° to 0.002 barns at 90° in the cm system.

* The work described was sponsored by the AEC.
[1] J. Hadley *et al.*, Phys. Rev. **75**, 351 (1949).

E9. Nuclear Cross Sections for 95 and 270 Mev Neutrons (Measured with Bismuth Fission Chambers).* J. DEJUREN, N. KNABLE, B. MOYER, *University of California, Berkeley.*—Total and inelastic nuclear cross sections for 95 and 270 Mev neutrons have been measured using bismuth fission chambers. The 95 and 270 Mev neutrons are produced by bombarding a Be target with 190 Mev deuterons and 350 protons respectively in the 184-in. cyclotron. Total cross sections were measured using good geometry, and a special geometry was devised so that inelastic and total cross sections could be measured simultaneously. The total cross sections of the elements measured from deuterium to tin at 270 Mev are all 0.57 to 0.58 times their values at 95 Mev. The ratio of inelastic to total cross sections was about 0.40 for heavy elements at 95 Mev. At 270 Mev, σ_i/σ_t is nearly 0.50 for both Cu and Pb, which is the value obtained for opaque nuclei at "low" neutron energies.

* This work was sponsored by the AEC.

E10. Total Cross Sections of Nuclei for 280 Mev Neutrons. R. FOX, C. LEITH, K. MCKENZIE, L. WOUTERS, *University of California, Berkeley.*—The measurement of 280 Mev neutron cross sections of various nuclei will be described. The neutron beam used results from 350 Mev protons in the 184-in. cyclotron striking a 2-in. Be target. The neutron detector consists of a double coincidence anthracene scintillation counter telescope which counts recoil protons scattered at 15° from a paraffin cylinder placed in the collimated neutron beam. A 2-in. Cu absorber placed between the two counters assures that only protons of energy greater than 250 Mev are counted. The cross sections for all nuclei measured from Li to Pb are smaller than the corresponding cross sections measured at 90 Mev[1] by factors between 0.5 and 0.6. This work was sponsored by the AEC.

[1] Cook *et al.*, Phys. Rev. **75**, 7 (1949).

E11. The Energy Dependence of Several Organic and Inorganic Counters. R. H. DAVIS AND J. D. GRAVES, *Naval Radiological Defense Laboratory.*—The energy dependence of naphthalene, anthracene, stilbene, $CaWO_4$, KI(Tl), KBr(Tl), and the 1P21 photomultiplier tube has been determined in the energy ranges from 30 to 185 effective kv x-radiation and for radium gamma-radiation. The sensitivity of thalium activated potassium iodide shows a broad maximum in the energy range from 85 to 175 kv effective of about 40 times the gamma-ray sensitivity. Potassium bromide shows a sensitivity relative to the gamma-radiation of about 5 in the range from 45 to 190 kv effective, having a maximum of about 8 at 60 kv effective. Calcium tungstate is nearly energy independent in the region from 60 to 185 kv effective, having a sensitivity of about 16 relative to radium gamma-rays. Anthracene exhibits a generally increasing sensitivity relative to the gamma-radiation from about 1 to 3 in the energy region from 30 to 160 kv. In this same range the relative sensitivity of naphthalene increases from about 1 to 2 and that of stilbene from about 2 to 7. The response of the 1P21 relative to gamma-radiation is about 42 at 55 kv and decreases to about 5 at 190 kv.

E12. Temperature Dependence of a Scintillation Counter Using Several Organic and Inorganic Phosphors. G. E. KOCH AND J. D. GRAVES, *Naval Radiological Defense Laboratory.*—The temperature dependence of the gamma-counting efficiency of stilbene, calcium tungstate, thalium activated potassium iodide, and potassium bromide has been investigated in the region between −196°C and +50°C. The total current output from the 1P21 Photomultiplier was measured by metering the plate current in a direct coupled amplifier. The temperature and response for the end point and maxima and minima of the curves for these materials are shown in Table I using arbitrary response scales.

TABLE I.

Material	Temperature	Maximum	Minimum
Stilbene	−196°C		40 (end point)
	−100°C	225	
	+40°C		80 (end point)
Calcium Tungstate	−196°C		35 (end point)
	−30°C	110	
	+60°C		63 (end point)
Potassium Iodide	−76°C		50 (end point)
	−15°C	150	
	+35°C		100
	+50°C	145 (end point)	
Potassium Bromide	−76°C	63 (end point)	
	−35°C		40
	+60°C	100 (end point)	

E13. A Calibrated X-Ray Film Badge Dosimeter. E. TOCHILIN, R. H. DAVIS, J. CLIFFORD, HMC, USN. (*Introduced by R. I. Condit.*)—An x-ray film badge dosimeter has been developed which will allow a quantitative interpretation of roentgen dose received for effective energies of 15 kv to 150 kv. The dosimeter is able to cover a range of intensities from 0.1 r to 2.0 r. Both duPont type 552 insensitive film and Eastman radiatized type DF-7 dental film have been calibrated for use with the dosimeter. The film is covered by an echelon of three metal shields plus an open window region. Tables are presented in which the ratio of film densities between two adjacent shields determine a factor which, when multiplied by the net density under a given shield, gives the radiation received directly in roentgen units. Data are also included which allow the dosimeter to be used to determine the effective energy of x-radiation, direct or scattered, striking the film badge. Proper processing of exposed film is accomplished by a one-point calibration check and consists of developing a pre-exposed "Density Standard" film for various developing times until a net density of 1.5 ± 0.15 is obtained. The films can be developed in any commercially available x-ray developer.

E14. The RCA 1P21 Photomultiplier Tube as a Gamma-Ray Detector. J. D. GRAVES AND G. E. KOCH, *Naval Radiological Defense Laboratory.*—The characteristics of the 1P21 photomultiplier tube used as a gamma-radiation detector have been studied. The response of the tube has been determined by metering the total current output. The range of radium gamma-intensities observed have been from 0.001 r to 100 r per hour. The response of the tube is linear throughout this range. The tube exhibits no directional dependence in the plane

perpendicular to its axis. In the plane containing the axis of the tube a 28 percent variation in response is observed for a point source 40 cm from the tube. Minimum response occurs for the gamma source on the axis of the tube. A 0.6 percent per degree centigrade decrease in response is observed with increasing temperature in the region of room temperature. A one percent increase in applied voltage results in a 10 percent increase in response.

WEDNESDAY MORNING AT 9:30

Physics Hall, Room 334

(H. MARGENAU presiding)

F1. A Portable High Intensity Magnet and Cloud Chamber for Use in Cosmic-Ray Research.* D. S. POTTER, J. E. HENDERSON, C. E. MILLER, AND JAY TODD, JR., *University of Washington.*—Two identical relatively light weight electro magnets with cloud chambers for use in high altitude cosmic-ray research have been constructed. The magnets can be used independently or in combination. The total weight including the frame-work is 5000 pounds, of which 2000 pounds is copper while the steel casing and core weigh 2000 pounds. This weight meets the requirement for use in a B-29 bomb-bay. At 10,000 gauss the current density is 5000 amperes per square inch in the copper, and the power consumption is 50 kw while at 8000 gauss the power consumption is 25 kw. The, Joule heat is removed by oil flowing at 60 g.p.m. through each magnet. The temperature is regulated to within 0.01C° and the field is uniform to one percent over the entire illuminated region of the chamber. The 17 cm cloud chamber has an illuminated depth of 2.5 cm. Expansion takes place through a two-inch tube in the core of the magnet. The chamber is photographed through a hole in the other core. The magnet and automatic chamber control units are conventional. To date this equipment has been utilized at sea level and 3.4 km at Climax Colorado.

* Supported by Bureau of Ordnance, USN, under the technical supervision of the ONR.

F2. Cosmic-Ray Protons at 3.4 Km.* JAY TODD, JR., J. E. HENDERSON, C. E. MILLER, AND D. S. POTTER, *University of Washington.*—Of 18,000 counter-controlled cloud chamber photographs taken at Climax, Colorado (elevation 3.4 km) at field strengths of 8,000 and 10,000 gauss, approximately 200 protons which are unaccompanied by other time coincident tracks have been identified (by means of ionization and momenta). In addition, about a fifth as many protons accompanied by one or more lightly ionizing time coincident particles have been found. With no absorber above the chamber single identifiable proton tracks constitute two percent of all single tracks. Since the momentum spectrum is not distorted above 350 Mev/c by failure of the protons to trip the lower counter, and the ionization below 500 Mev/c is sufficiently high to make identification fairly certain, this interval provides a good basis for estimating the percentage of protons in the penetrating component in this momentum range. This value is estimated to be about ten percent.

* Supported by Bureau of Ordnance, USN, under the technical supervision of the ONR.

F3. The Penetrating Component of Cosmic-Rays at 3.4 Km.* C. E. MILLER, J. E. HENDERSON, D. S. POTTER, JAY TODD, JR., *University of Washington.*—Using the knowledge of the momentum spectrum of protons and the momentum spectrum of all ionizing particles, an analysis of the penetrating component of cosmic rays at 3.4 km into protons and mesons can be made. A momentum spectrum for all ionizing particles similar to that found by Adams *et al.* at 30,000 feet has been found. A meson maximum has been found at a momentum of about 500 Mev/c, which is about the value of the proton peak of reference 1. The 3.4 km data indicate a proton peak at a higher momentum. The protons which form the strong maximum at about 500 Mev/c at 30,000 feet would be absorbed before reaching 11,000 feet (neglecting production). This interpretation of the 3.4 km no lead absorber spectrum is also consistent with our results obtained under absorbers of 5 and 20 cm of lead.

[1] R. V. Adams *et al.*, Rev. Mod. Phys. **20**, 334 (1948).

* Supported by Bureau of Ordnance, USN, under the technical supervision of the ONR.

F4. A Precision Determination of the Energy of the 1.1 and 1.3 Mev Gamma-Radiations from Co^{60} by Direct Crystal Diffraction. D. A. LIND, J. R. BROWN, J. W. M. DUMOND, *California Institute of Technology.*—Recent improvements in the focusing curved crystal gamma-ray spectrometer have extended its energy range and yielded much better luminosity and resolving power than obtained initially. These are: (1) new crystal holder—aperture 1.7×2 inches, focal length 196 cm, resolution 0.05 x.u. giving twofold gains in both luminosity and resolving power; (2) new collimator—24 die-cast tapering lead partitions 30 inches long with 25 tapering spacers, thickness of both partitions and spacers 40 mils at entry end. Geometrically this can accept the diffracted beam and block the transmitted beam for angular differences between them as small as 8 minutes giving a calculated (theoretical) upper working limit of 3 Mev, a threefold improvement over previous collimator. Wave-lengths and energies of two gamma-rays emitted following β-decay of Co^{60} have been measured with this new equipment using a source of 50 mc and found to have values of 9.307 ± 0.005 x.u. and 10.584 ± 0.005 x.u. corresponding to 1.3318 ± 0.0010 and 1.1171 ± 0.0010 Mev, respectively. The lines appear to have equal intensities. The integrated reflection coefficient of the (310) planes of the curved quartz crystal appears to follow a λ^2-dependence on wave-length down to 9 x.u., the shortest so far observed.

F5. Study of Ions Formed in a Hg Resonance Cell Containing N_2. R. H. BROWN, *University of Washington.*—When sufficiently pure N_2 is admitted into a Hg resonance cell excited by unreversed $\lambda2537$, ions may be formed in sufficient quantity to produce image forces of several dynes/cm² on a metal foil. The foil forms one plate of a capacitor in an IF bridge which permits detection of a shift of as little as 0.2A in the average position of the foil. By illuminating with $\lambda2537$ from a pulsed RF-excited electrodeless Hg discharge, ion decay data are obtained. The observed image forces are a maximum for roughly 12 cmHg of N_2, and on extinction of the exciting radiation decay approximately as exp minus $(A+B/p+Cp)t$, for p between 1 mmHg and 50 cmHg of N_2. Unless great precautions are taken to remove traces of H_2 and H_2O from the N_2, A and C are so large no observable ions are formed. Minimum decay constants of between 100 and 200 $sec.^{-1}$ have been obtained at room temperature with 7 cmHg of N_2 and 0.002 mmHg of Hg vapor. With neglect of the effects of surface emitted electrons, image forces are proportional to the square of the exciting $\lambda2537$ intensity, which indicates that

formation of an ion pair involves the collision of a Hg atom in the 6^3P_0 state with another excited body.

F6. Work functions of Gas-Coated Silver Surfaces. G. L. WEISSLER AND T. N. WILSON, *University of Southern California*.—Average electronic work functions of silver surfaces, subjected to glow discharges in various gases, were determined by a method first suggested by C. W. Oatley.[1] The procedure used was similar to the one described earlier for gas coated surfaces of Ta and W.[2] By measuring the contact potential between a cold cylinder and a concentric hot W-filament one can obtain the work function of the cylinder surface assuming the filament has a known work function. When the cylinder surface was subjected to glow discharges in various gases, positive or negative ions were driven onto the surface and formed a gas film over a vacuum evaporated silver layer. Results will be presented for the following gas treatments: Ag+He; Ag+A; Ag+N_2; Ag+H_2; Ag+O_2; Ag+H_2O; Ag+Freon 12. Oxygen and freon, both forming negative ions, produced the most significant changes in work functions by increasing them by about 1.4 ev. Gas films of these gases seemed very stable even to strong positive ion bombardment with A or He;—both N_2 and H_2 showed a decrease of the work function by a few tenths ev, whereas A and He did not seem to affect the surface. Water vapor, when admitted to the baked-out system on a freshly prepared Ag layer, showed a slight increase in the work function. Further work on Au and other surfaces is in progress.

[1] C. W. Oatley, Proc. Phys. Soc. London, **51**, 318 (1939).
[2] G. L. Weissler and R. W. Kotter, Phys. Rev. **73**, 538A (1948).

F7. Thermal Noise at Very High Frequencies. A. VAN DER ZIEL, *University of British Columbia*.—In his well-known paper on thermal noise Nyquist[1] found for the available noise power P_a in a frequency interval $\Delta\nu$:

$$P_a = kT\Delta\nu. \quad \frac{h\nu}{kT}(e^{h\nu/kT}-1)^{-1},$$

from thermodynamical considerations Burgess[2] found the same formula for the available noise energy of an antenna enclosed in a hollow sphere of uniform temperature T. It will be shown that the latter result can be obtained from a very simple argument. From the electron theory Spenke[3] found $P_a = kT\Delta\nu$ even for frequencies for which $h\nu/kT \geqq 1$; it will be shown that this is due to the fact that the interaction between the motion of the electrons in the lattice and the lattice vibrations was not fully taken into account.

[1] H. Nyquist, Phys. Rev. **32**, 110 (1928).
[2] R. Burgess, Proc. Phys. Soc. **53**, 293 (1941).
[3] E. Spenke, Wiss. Veroff Siemens Werken **18**, 55 (1939).

F8. Some Results in the Scattering Theory of the Dirac Equation. G. PARZEN, *Stanford University*.—While treating the problem of investigating the charge distribution in heavy nuclei by means of 1 Bev electron scattering, the following results have been obtained. Let $g_L(r)$, $f_L(r)$ be the radial parts of the wave function,[1] $g_L(r) \to \cos(kr+\eta_L) = \sin(kr - L\pi/2 + \delta_L)$, and let $g_L(r) = S_L + \bar{S}_L$, $f_L(r) = (S_L - \bar{S}_L)/i$, then an approximate expression for the phase shifts equivalent to the Born Approximation is (in relativistic units) $(e^{2i\delta_L}-1)/2i = \frac{1}{2}(E+1) \times (\Delta_L + k^2/(E+1)^2 \cdot \Delta_{L+1})$ and $(e^{2i\delta_{-L-1}}-1)/2i = \frac{1}{2}(E+1)(\Delta_L + k^2/(E+1)^2 \cdot \Delta_{L-1})$, where $\Delta_L = -2k\int_0^\infty j_L^2(kr)V(r)r^2dr$. By means of a variational principle, two other approximate expressions f or η_L were found. Let s_L, δ_L be solutions for the potential $V_0(r)$ with the phase shifts η_L^0, then we have $\eta_L - \eta_L^0 = -(E/k)\cdot\int_0^\infty (V-V_0)(s_L\delta_L + (s_L^2+\delta_L^2)/2E)dr$. This result for $V_0(r) \equiv 0$, reduces to the BA except that $(e^{2i\delta_L}-1)/2i$ is replaced by δ_L. A second variational result is

$$\eta_L - \eta_t = a\sin\varphi - a\sin(2(\eta_t - \eta_L^0) + \varphi) - (E/k)\int_0^\infty (V-V_0)(s_L\delta_L + (s_L^2+\delta_L^2)/2E)dr,$$

where $ae^{i\varphi} = \int_0^\infty ((L+1)/r + iV/k)s_L^2 dr$ and $\cos(2(\eta_t - \eta_L^0) + \varphi) = 1/2a$. For high energies the two variational results approach each other.

[1] N. F. Mott, Proc. Roy. Soc. **124**, 426 (1929).

F9. Potential and Gradient Distributions in Parallel Plane Diodes at Currents below Space Charge Limited Values. WILSON M. BRUBAKER, *Westinghouse Research Laboratories*.—The equations for electron motion in a plane diode under the influence of space charge are integrated. The solution is expressed in terms of four dimensionless numbers, normalized so that their range is from zero to unity. The gradients at the cathode and at the anode are expressed as functions of the current density as it varies from zero to space charge limited values. Space distributions of potential and gradient are given in terms of the location of the plane of interest between the cathode and the anode for a number of specific current densities. Evidence is shown of the existence of a plane for which the gradient is essentially independent of the current density.

F10. A Logical Extension of the Field Equations of General Relativity. CORNELIUS LANCZOS, *National Bureau of Standards* and *University of California, Los Angeles*.—Consider a Riemannian space, controlled by an action principle which is quadratic in the curvature components. The resultant field equations, if expressed in the g_{ik}, are complicated differential equations of fourth order, and the objection can be raised that simpler invariant field equations of only second order—the Einsteinian field equations—may be found. The same variational problem is now approached from a modified mathematical angle, considering the curvature components R_{iklm} as the basic field quantities. The resulting algebraic minimum problem is restricted by the Bianchi identity, which in specifically four dimensions takes the form of a divergence equation. The method of the Lagrangian multiplier gives rise to a new field tensor of third order $H_{ik}^{\ m}$, antisymmetric in i, k, in remarkable analogy to the curvature tensor $\Lambda_{ik}^{\ m}$ of Einstein's theory of "distant parallelism." The resultant field equations are now of only second order and appear as a generalized system of gravitational equations. The Einsteinian field equations represent a special subclass of the general solution. The place of electromagnetism in this theory cannot be decided without studying the behavior of the fields of second order. The present investigation does not go beyond the first order approximation.

F11. An Electrodynamic Examination of the Hydrogen Atom. DAN MCLACHLAN, JR., *University of Utah*.—In an attempt to devise a classical model of the hydrogen atom which fulfills two requirements, (a) only discreet energy states are stable, and (b) energy is not lost by radiation while in a stable state, it is assumed that the positive and negative charges are mutually sources and sinks for one another's radiation. It is first shown that the product of the radiation of one of the charges and the receptive power of the second is independent of which charge is considered the source. It is then assumed that the variation of the effective index of refraction in the space between the charges is such as to focus the radiation from one charge to its partner. The two conclusions deduced from this model are (a) the distances between the electron and the proton in the hydrogen atom are restricted to multiples of one half wave-length of the standing wave between them, and (b) the high indexes of refraction required for focusing results in an elongation of the standing waves by a factor in the neighborhood of 2000 upon escape from the atom into free space. Since the introduction of this concept of index is the chief contribution, methods for calculating it are described using a doublet to explore the field.

F12. On the Theory of the Establishment of Flow in Water Entry.* EUGENE P. COOPER, *U. S. Naval Ordnance Test Station, Pasadena Annex.*—When a solid object passes across an air-water interface, a complex flow, whose most obvious manifestation is the phenomenon of splash, is established in the water. The mathematical description of this flow-establishment involves potential theory primarily. However, classical potential theoretic methods are not directly applicable because the requirement that the pressure be constant at the water surface is, in terms of velocity potential, only an implicit boundary condition. A particular type of entry situation is considered, namely, oblique entry of a half-plane of infinite inertia. An attempt is made to obtain an approximate solution in the form of a time-parametric steady state solution. This attempt is shown to lead to divergences. The transient nature of the phenomenon must be explicitly included in the mathematical description. Methods are developed for solving the problem by iterative numerical procedures. The most important characteristics of the observed flow are shown to be in good agreement with the theory.

* This investigation was supported by the ONR.

F13. Infra-Red Studies with the Perkin-Elmer Spectrometer. A. M. CROOKER, *University of British Columbia.*—A comparison has been made between the different methods of calibrating a model 12-B Perkin-Elmer spectrometer to the NaCl limit at 15 μ. There appears to be a small shift in calibration probably due to temperature variation, so that for accurate frequency determinations one must calibrate the unknown absorption frequencies from internal standards. Experience with several calibration procedures indicates that a power series with cubic terms can be fitted to the internal standards rapidly and with residuals of the order of the reproducibility of instrument readings. Results on observations in the absorption spectra of CS_2 and the isomers of decalin will be presented.

F14. Handedness in Space-Time and the Nature of Magnetic Poles. M. AVRAMY MELVIN, *Eastsound, Washington.*—Handedness transformations, or odd permutations of a base vector set, in 3+1 dimensional space-time fall naturally into four types: two reducing to the familiar mirrorings, and inversions through a point, of pre-relativistic physics; and the other two involving reversal of time components of space-time objects. Since ordinary regions of space-time are free from any intrinsic handedness (except possibly for time-asymmetry), any physical theory should be invariant under handedness transformations (except possibly for time-reversals). Dirac's new theory of magnetic poles is not at all handedness-invariant. In trying to set up a theory of unisolated atomistic particles, which yet have statistical macroscopic manifestations, we may be able to make symmetry deductions from the latter. This is the case with the theory of magnetic poles: To insure handedness-invariance, one or the other, charges or poles, in the Maxwell-Heaviside equations with which the theory begins, must have pseudoscalar symmetry. Which is pseudoscalar is also determinate: Reviving, in relativistic form, an old argument of Voigt from the general Symmetry Principle and phenomena in crystal physics, it is shown that magnetic pole is the pseudoscalar entity.

WEDNESDAY AFTERNOON AT 2:00

Auditorium of the Health Sciences Building

(W. WENIGER presiding)

Joint Session with the American Association of Physics Teachers

Invited Papers

G1. An Infra-Red Recording Spectrograph of High Resolution and High Precision. EDSON PECK, *Northwestern University.* (30 min.)

G2. Solar Activity Variations and Their Apparent Consequences. WALTER O. ROBERTS, *Harvard University.* (30 min.)

G3. The New California Institute Electrostatic Generator. J. E. PERRY, *California Institute of Technology.* (30 min.)

G4. Theory and Applications of the Shock Tube. OTTO LAPORTE, *University of Michigan.* (30 min.)

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To avoid serious delay in the appearance of the Bulletin, joint papers are indexed only under the name of the first author.

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